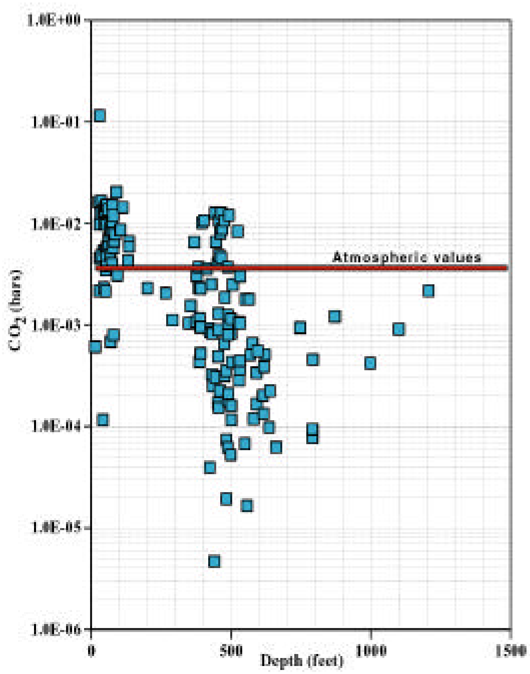
added is 34 liters, and the amount of ^{124}Xe to be added is 0.03 liters. Both very small and inexpensive amounts. We are taking into consideration the monitoring ratio of 100:1 because the tracer test should be applicable to surface monitoring. Here we are assuming that at the Earth's surface, we will want to detect leaking CO_2 that is at a level that represents only about one percent of the natural soil CO_2 present. As discussed below, this is a very conservative assumption. Also, as presently conceived, the tracer test would at least initially be a well-to-well test of liquid CO_2-noble gas migration, and the stated ^3He and ^{124}Xe concentrations are far higher than would be needed for such a test.

The Mabee results also allow us to design a surface monitoring strategy for actual-case CO_2 storage. Here we could use as an example the Rangely, Colorado experimental CO_2 storage site. For this the assumptions are: (1) final storage volume ~$3x10^{10}$ m^3 of CO_2; (2) background xenon concentrations in the CO_2 are similar to the Mabee wells; (3) atmospheric xenon concentrations are ~$9x10^{-11}$ (volume fraction, STP); (4) the detectable ^{124}Xe isotopic shift due to the tracer is 0.1% (this easily obtained by LLNL mass spectrometers); (5) the ratio of soil CO_2:leaked CO_2 is 1:1. The total amount of xenon tracer that would have to be added during over the course of storage injection would be 5 liters. Relative to the amounts of commercially available xenon tracer, this amount is small. The xenon cost would be approximately $10,000. It should be noted that our strategy is designed to detect leaked CO_2 that represents half of the soil CO_2 present (i.e., 50% of the CO_2 present came from the leaking reservoir). An increase of this magnitude is far below levels that would affect vegetation, so is below the levels detectable through remote sensing. An increase of this magnitude is also well within the range of natural variations in soil CO_2 contents (Figure 5), and so would not be detectable by CO_2 monitoring alone.

Figure 5. Soil CO_2 concentrations through a 1000 foot soil profile. It may be desirable to monitor the noble gases for leaking CO_2 in wells drilled to these depths.



2.4.5.8 Conclusion

There are several results of this project relevant to the use of noble gas isotopes as monitoring tracers in CO_2 storage:

(1) The Mabee test results clearly show that the noble gas isotopic fingerprints dissolved in injected supercritical CO_2 can be recognized in CO_2 gas being released from the formation. In our case the release was of course due to the oil production well, but CO_2 gas evolved from leakage of stored CO_2 would provide a similar signature.

(2) The ability to detect the noble gas isotopic fingerprints in released CO_2 is easily within the analytical capabilities of current mass spectrometric methods. With appropriate tracer amounts added to stored CO_2, ground surface monitoring for noble gases can be achieved.

(3) The noble gas concentrations observed in the Mabee wells provides a guide for the amounts of noble gas tracer that will have to be added to CO_2 streams for the purposes of ground surface monitoring. The amounts are small relative to available supplies, and would be inexpensive relative to total costs of CO_2 storage. It is economical to add sufficient tracer that the noble gases would be detectable long before the increase in CO_2 was detected at the surface. The noble gases would thereby become an early warning system for CO_2 leakage.

(4) The Mabee results permit the development of a proof-of-principle field demonstration of noble gas monitoring methods. This demonstration could be designed such that short-term results can be obtained through well-to-well tracing, followed by long-term monitoring at ground surface.

(5) In order to design a truly effective surface monitoring system and avoid over-engineering such a system, numerical simulations - computer models - of the migration behavior of the noble gases relative to CO_2 will be required. Such models will be site specific for each storage site, taking into account local geology and hydrology. However, monitoring in regions of broadly similar geology and hydrology, such as the Permian Basin, may require only one general model.

(6) An examination of previous results of monitoring noble gas migration reveals that small-ion noble gases (here, ^3He) migrate less rapidly than large-ion gaseous complexes (here, SF_6). This raises the possibility that large-ion noble gases (e.g., Xe) may migrate to ground surface more rapidly than CO_2. If so, xenon isotopic tracers may be detection precursors to leaked CO_2, and thereby enhance their early warning capability (as in point 3 above). The ^3He and SF_6 migration has been accurately modeled using the NUFT modeling code employed in this project. Future modeling efforts will be directed at this early warning concept.

In summary, the results of this project have demonstrated that noble gas isotopic tracing presents a viable, inexpensive, and effective means of monitoring CO_2 migration. Further work could provide a proof-of-principle field demonstration, and could assess the possibility that noble gas tracers would provide an enhanced early warning system for CO_2 leakage.

This project received a very unexpected 40% reduction in total project funding during FY03. No funds have been received from the DOE to this point in FY03. CCP funding (through British Petroleum – America) was terminated in March, 2003. The project has been without funding during most of the reporting period of this Technical Report. Due to this, Project Components II and III were suspended during this reporting period.

2.4.5.9 References

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2.4.5.10 List of Acronyms and Abbreviations

atm	Atmospheres (of pressure)
Bcf	Billion cubic feet
CCP	CO_2 Capture Project
EOR	Enhanced Oil Recovery
LLNL	Lawrence Livermore National Laboratory
MCFPD	Million cubic feet per day
STP	Standard temperature and pressure
He	Helium
Ne	Neon
Ar	Argon
Xe	Xenon

2.5 Integration and Communication

2.5.1 SMV Study Integration and Reporting

Report Title

CO_2 Capture Project - An Integrated, Collaborative Technology Development Project for Next Generation CO_2 Separation, Capture and Geologic Sequestration

SMV Study Integration and Reporting

Report Reference

2.5.1

Type of Report:	Semi-Annual Report / Final Report delete as applicable
Reporting Period Start Date:	February 2003
Reporting Period End Date:	July 2003
Principal Author(s):	Scott Imbus, CCP Team Lead
Date Report was issued:	July 2003
DOE Award Number:	DE-FC26-01NT41145
Submitting Organization:	CO_2 Capture Project
Address:	1776 I StreetNW, Suite 1000 Washington, DC 20006

1.2.1..1 Abstract

The purpose of this task is to develop a book (edited volume) and several overview articles based on results from the SMV team of the CO_2 Capture Project. We will develop a series of reports and publications that will be used to communicate the results of the SMV team's work to a variety of audiences that would benefit from this information. Target audiences include the staff of the member companies of the CCP JIP, technical specialists interested in geologic sequestration, NGO's, regulators, government officials, opinion makers, and the general public. The overview publications will be submitted between by November 30, 2003 with publication expected by mid-2004. The edited volume will be submitted by March 31, 200 and published before October 2004. This effort is being coordinated with the overall CCP integration and communications plan.

1.2.1..2 Table of Contents

2.5.1.3 Introduction

The CCP SMV team has contracted Lawrence Berkeley National Laboratory to implement a publication strategy that will disseminate the results of the ~30 SMV studies to diverse audiences ranging from technical specialists to the public. Table 1 matches the audience to the type of publication.

Audiences	Product	Description
• Technical staff from the member companies of the JIP • Technical specialists interested in geologic sequestration	Publication #1. Large compilation of technical papers (20-30 pages each) from all of the projects in the SMV; prefaced by an executive summary.	Peer reviewed, high quality technical document. Suitable for citation by the IPCC special study. Published as a book from a widely respected scientific society.
• Scientists and engineers being introduced to geologic sequestration, regulators	Publication #2. Technical review article, 20-30 pages long. Focused on major areas of the SMV, risk assessment, storage optimization, storage integrity and monitoring and verification.	Technical article to be published in widely distributed technical journal (e.g. JPT, Oil and Gas Journal).
• NGOs, regulators, government officials, public with an interest in science and technology, press	Publication #3. Technical review article, 20-30 pages long. Introduction to geologic storage followed by a description of the major areas of the SMV project, risk assessment, storage optimization, storage integrity and monitoring and verification	Article for a broad audience published in a widely read journal such as Scientific American or the equivalent.
• Government officials, scientific opinion makers, NGOs, scientific press	Publication #4. Short "State of the Technology Article" (3-5 pages) for highly influential scientific audience and government leaders.	Short article for high impact scientific journal (e.g. Science or Nature).
• General public, NGOs, press, educators, regulators being introduced to the technology	Publication #5. Brochure or pamphlet on geologic storage that highlights the contributions of the CCP JIP.	Hard copy and web-based description of geologic storage targeted to a non-technical audience. Emphasis on contributions of the CCP to geologic storage. Emphasize benefits of technology.

Table 1. Suggested products from the SMV Team for dissemination of results.

The following outlines the deliverables for the project:

1. Publication #1. Prepare an executive summary, introduction and conclusions that would introduce and summarize a compilation of all of the papers for each of the SMV projects. Organize and oversee a peer review for all of the final papers delivered to the SMV team.

2. Publication #2. In consultation with the SMV team, prepare a review article (approximately 30 pages) of the results from the SMV teams work. Submit to a widely available journal for technical specialists interested in geologic sequestration (e.g. JPT, Oil and Gas Journal, or others at the suggestion of the SMV team).

3. Publication #3. In consultation with the SMV team and the SMV team's communications consultant, prepare a review article (approximately 30 pages) of the results from the SMV teams

work. Submit to a widely available journal for broad audience (e.g. Scientific American or others at the suggestion of the SMV team).

4. Publication #4. In consultation with the SMV team, prepare a short “State of the Technology” paper (approximately 3-5 pages) based on the results of the SMV teams work. Submit to a highly prestigious journal (e.g. Science or Nature).

5. Publication #5. Provide technical assistance to the SMV team’s communications consultant to prepare a brochure or short pamphlet for the general public about Geologic Sequestration and the SMV team’s projects.

1.2.1..4 Executive Summary

The storage, monitoring and verification portion of the CCP is comprised of ~30 projects in varying stages of completion. The scope of these projects cover several aspects of CO_2 sequestration including integrity (suitability of natural and engineered systems),optimization (taking advantages of economic byproducts such as EOR and ECBM or improving efficiency), monitoring (assessing the performance) and risk assessment (quantifying potential hazards). For these studies to be useful in advancing CO_2 geologic sequestration technology and decision making, a coordinated and timely rollout of results is needed. Of particular concern is the IPCC (Intergovernmental Panel on Climate Change) meeting in December 2004 which will consider the merits of geological sequestration technology for carbon mitigation. For consideration, the review panel will require peer-reviewed articles such as those envisioned for the technical volume. Other review articles will assist policy makers in understanding geological CO_2 sequestration and help engage NGOs and the general public (see Table 1 in introduction).

The following excerpt is taken from the book proposal (for the technical volume) to the American Geophysical Union (AGU):

Geologic storage of CO_2 is quickly emerging as a leading candidate for deep reduction of atmospheric CO_2 emissions. This book will provide a comprehensive set of new research papers on this topic based primarily on a three-year international industry/government sponsored project called the CO_2 Capture Project (CCP). This book would provide the most comprehensive anthology of research papers on this topic to date. The CCP sponsored 30 research projects to develop new information on five topics that are critical to the success of geologic storage of CO_2: 1) storage integrity, 2) optimization of CO_2 storage, 3) monitoring technology and approaches, 4) health, safety and environmental risk assessment, and 5) socioeconomic considerations.

An additional excerpt is aimed at justifying the size of the potential audience:

There is a rapidly growing research community that is interested in this subject. Conferences, technical sessions at AGU, and workshops typically attract several hundred researchers. Active participants in the field are likely to want this "benchmark" book for their libraries. Faculty members and students wishing to quickly get familiar with this topic are likely to be interested in this book. It may also serve as a text book for research seminars or graduate classes. In addition, regulators, companies and NGO's are also likely to be interested in the book. In addition, university libraries are also likely to be interested in this book.

To date, a provisional table of contents has been submitted with editors form Lawrence Berkeley Laboratory (Benson, Oldenburg and Hoversten), Shell (Mass) and ChevronTexaco (Imbus)(see Results and Discussion). Selected outside contributors from other JIPs and government agencies (e.g., NR Canada) may be invited to contribute.

1.2.1..5 Experimental

There were no experiments conducted for this study.

1.2.1..6 Results and Discussion

To date, results are available for the AGU technical volume only. Reproduced below is the proposed provisional table of contents for this volume submitted:

Proposed Table of Contents

Monitoring and Verification

Human Health and Environmental Risk Assessment

The table of contents represents all of the major categories of the CCP-SMV program. Additional chapters might include policy considerations.

1.2.1..7 Conclusion

The integration and communications plan is aimed at dissemination the findings of SMV researchers to a broad audience, ranging from technical specialists to policy makers, NGOs and the general public. To date, a book proposal has been submitted to the AGU. The provisional table of contents covers the principal focus areas of SMV (integrity, optimization, monitoring and risk assessment). This technical volume and the other planned publications are relevant to promoting CO_2 geological sequestration stakeholders. At present, such integrated information is not available in the literature.

2.5.1.8 References

None.